PAPERS BY PUPILS OF THE PLANE GEOMETRY CLASSES OF FULLERTON UNION HIGH SCHOOL

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Toward the end of last school year nearly every member of our plane geometry classes undertook, in addition to his regular class work, the preparation of a paper on any subject of interest to him. The subject, chosen without reference to mathematics, was investigated to see whether or not it was in any way dependent upon, or connected with, mathematics. This plan originated with the pupils of the classes—probably as a reaction to the class work, which was designed to stimulate thought along that line.

The papers contained nothing new and startling—they added nothing to the total knowledge of the world; but they did give a considerable amount of knowledge, and much interest, to the students. The time devoted to the papers did not seem to detract from the quality of the regular class work, for in classes aggregating about one hundred there was but one failure, and many exceptionally good records.

The list of topics which were selected by the pupils comprise: Architecture, Art, Astronomy, Blood Enumeration, Bridge Construction, The Chemical Engineer, Commerce, The Construction of an Automobile, Dam Building, The Development of Mathematical Symbolism, The Engineer in the War, Geometry in Primitive Art, Headlights for Automobiles, Higher Mathematics in the Business World, Irrigating Systems, Life Insurance, The Los Angeles Aqueduct, Mathematics in General, Mining, Music and Mathematics, Navigation, Oil Production, Petroleum, Plumbing, Proportion in Everyday Affairs, The Pythagoreans, Railroad Surveying, The Refining of Petroleum, Road Building, and A Trip to an Airplane Factory.

To the mature person most of these topics obviously involve mathematics, but to the pupils this was, in many cases, not at all evident. It will be noticed that no attempt was made to confine the subject to geometry; one very wholesome feature of the project was that students had forced upon their attention the fact that geometry is but one branch of a very large subject.

To give the reader an idea of the quality of these papers we print herewith the one on Navigation and the one on A Trip to an Airplane Factory.

NAVIGATION

By Douglas McGill

Navigation,* which affords a knowledge necessary to conduct a ship from place to place and by which a mariner may determine his ship's location at any given moment, is divided into two branches, namely: piloting and nautical astronomy.

Piloting is the most important part of navigation and requires the most skill, vast experience, the best of judgment, and wits always on the alert. In the navigation of the high seas, where nautical astronomy is employed, if an error is made in directing the ship's course, it is an easy matter to correct it by a later observation. But in the branch of navigation known as piloting, if an error is made, the result is frequently a disaster, since it is employed upon the approach to land. A ship, the navigator is taught, is usually safe on the high seas, and danger threatens upon the approach to land.

As his ship draws near land the pilot has ready the very latest charts, and particularly a large "scale" map, of the locality, showing shoals, lighthouses, buoys, etc. On this he finds the position of his ship. When conditions are fair his work is not hard, but should bad weather exist or low fogs menace, his work is of the most serious nature and his nerves are frequently racked at the responsibility with which he is burdened.

The navigator, when in sight of objects whose position is shown on the charts, may locate his ship's position by any one of the following methods:

A—Cross bearing of two known objects.

B—Bearing and distance of a known object.

C—Bearing of a known object and the angle between two known objects.

*My sources of information were:

(1) American Practical Navigator, by Bowditch. Published by U. S. Hydrographic Office, under the authority of the Secretary of the Navy.

(2) Navigation, by Harold Jacoby. Published in New York by Macmillan Co.

(3) Mr. Olsen, who was formerly a captain on Norwegian ships.

(4) Mr. H. Lindville, the First Mate on the ship Lily, which plies between Mexican waters and San Pedro.

D—Two bearings of a known object separated by an interval of time with the distance during that interval.

E—Angles between three known objects.

Frequently, in the application of these methods, Trigonometry is employed. There are many cases, however, where Plane Geometry is used.

Where it is possible to get a bearing on a charted object the pilot has a valuable asset and a thing tangible with which to deal. It gives him the information that his ship is somewhere on that line, but the thing for him to know is, how far off he is from the charted object, for his chart shows him how far he must keep from that object to be in the safety zone. He employs, then, what is popularly known among mariners as the "bow and beam bearing," or the method as listed under *D*. An instrument called a "patent log" is towed at the stern, turning as it pulls through the water, registers automatically on deck the number of nautical miles traveled. This is read at the moment the charted object is 45° on the bow. (Fig. 1.) The same course is held until the object is directly abeam. This makes an angle of 90°, thus leaving the third angle $ACB =$ $45°$ or $180° - (90° + 45°)$. It is a geometrical fact that sides opposite equal angles are equal. Therefore, the distance the patent log registers will show how far the ship is from the charted object, for it registers the distance AB, and that is equal to BC. After consulting the chart, the pilot knows how near the danger zone he is taking his ship.

When it is known that a reef or shoals lie off the charted object, another method is used, since it may be seen that it might be extremely dangerous to wait until the ship is abeam before taking a bearing. This method is known as "doubling the angle on the bow," and is worked thus:—

A bearing is taken when the ship is, for example, 25° (Fig. 2) on the bow, and the log is read at the same time. The same course is held until the angle on the bow is 50°, or double the first angle. Here the log is again read. The angle ABC will be $180° - 50° = 130°$, and the angle ACB will be $180° - (130° - 25°) = 25°$. Therefore, the distance $AB = BC$ (sides opposite equal angles are equal), and the distance BC is the distance off the object when the second bearing was taken. In

case a strong current is running, the pilot must make allowance, otherwise the distance off the charted object would be in error.

A bearing of a known object and the angle between that and another known object is not often used, as it is preferable to take a cross bearing.

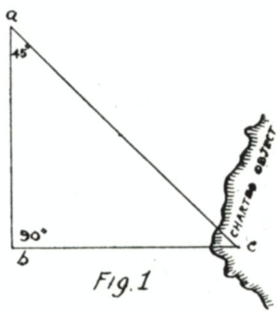

Fig. 1

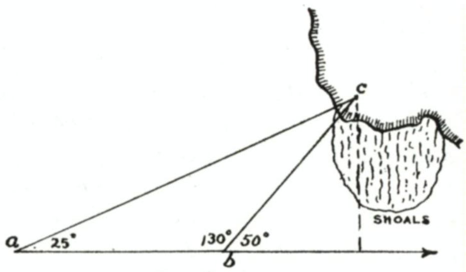

Fig. 2

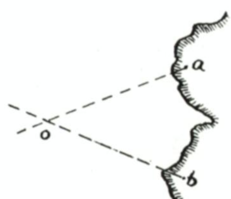

Fig. 3

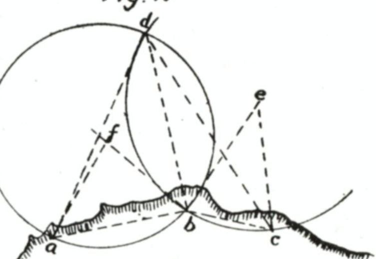

Fig. 4

A cross bearing of two known objects is determined thus: choose two objects which show unmistakably on the chart, observing the bearing, which each makes with the ship (Fig. 3). Then draw on the chart lines which make these angles and pass through the object *A* and *B*. The ship will be on some point on each line. Therefore, it must be on the intersection *O*, since that is the only point common to each line. Thus the pilot finding his ship located at a point *O* knows, from his chart, whether it is in safety or danger and holds his course or changes it as the case may be.

At times a third object is discernible. Here the same method is used, between the third object and one of the others. If, then, the point of intersection falls upon the point *O*, the pilot has checked the accuracy of his first "find."

The "Three Point" problem is much used among mariners. It is to find a point, such that three lines drawn from it to three given points shall form given angles with each other. The point to be located on the chart being the ship's location, A, B and C are the three charted objects along the coast. (Fig. 4.) The angle $C D B$ is observed to be 20° and the angle $A D B$ is 40°. Since the angle $B D C$ is 20° an angle at the center of a circle intercepted by the same chord would be double or 40°, and the angles formed by the radii of such a circle to the extremities of that chord would be $\frac{1}{2}(180° - 40°)$ or 70° each. Therefore, construct angles $E B C$ and $E C B = 70°$ each. With a radius $E B$ describe a circle. In the same manner construct angles equal to 50° each on the extremities of the line $A B$, then with a radius equal to $F B$ describe a circle intersecting the first drawn circle at D, which point located on the chart gives the correct position of the ship.

In navigation along a coast where many sunken rocks or shoals menace a ship there is a method used whereby a ship may pass through in safety between those charted ogres of the sea. This method is known among seafarers as the "Danger Angle." For example: Let S and S' be two sunken reefs with A and B two charted objects on shore (Fig. 5). In order to avoid the reef S', draw on the chart about the reef a circle, using as a radius the distance from the center of the reef to the point inside which the ship may not enter in safety. Construct, then, another circle which will pass through A and B and be tangent to the first circle at E. Draw the angle AEB.

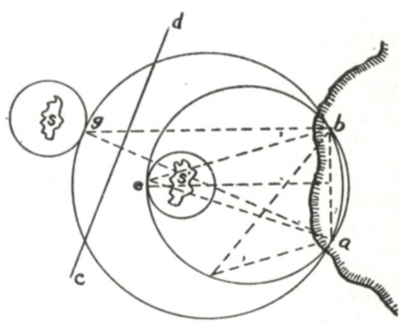

Fig. 5

It being a geometrical fact that the chord $A B$ will subtend equal angles at any given point on the circle, and greater angles at any point inside the circle, it will be seen, that so long as the ship passes on a course, such that the angle between it and the objects A and B never becomes greater than angle $A E B$, it will be safe so far as the reef, designated as S', is concerned.

To avoid the reef S, draw, as was done previously, a circle about S which will show how far from S the real danger lies. (This, of course, being shown on the Coast Pilot.) Then describe another circle which will pass through A and B and be tangent to the circle which lies about the reef S, at the point G. Measure angle $A\,G\,B$, and as long as the chord $A\,B$ subtends an angle greater than $A\,G\,B$ the ship will be within the circle $A\,G\,B$ and will pass between the dangers S and S'.

Thus it may be seen that upon the approach of land many problems present themselves. The pilot must, of necessity, make himself extremely familiar with his charts, must always have his instruments in perfect working order, but above all he must have an alert mind. He must never for a moment allow himself to be in doubt as to his ship's location and he must always check up his location as land marks appear. Whether it is passengers or freight which his ship carries, or whether it is only a ship traveling unladen, his responsibility is most grave, and it behooves him to know always that his observations are absolutely correct and that he is certain of the correctness of the solution of the navigation problems as they arise.

A Trip to an Airplane Factory

By William McBride

Aviation is the topic of the day. It is the ideal means of fast, comfortable and safe traveling. It has not yet arrived at perfection, but like the automobile it is beginning to come to the front as an economical means of conveyance.

Even though many of the people of the United States have ridden in an airplane, yet a very small percentage know the whys and hows of an airplane.

Let us pretend that we can take a trip through an airplane factory. We must also suppose that we own an airplane which will take us to the nearest factory in a short time.

First, we must get a pass which enables us to go through the buildings and grounds. A gentleman, who has seen service in the aviation department overseas, volunteers to show us through the plant. He leads us toward a large building some distance away. On the way there he explains to us the theory of an airplane.

''The airplane,'' he begins, ''is not such an intricate piece of mechanism as one might imagine. The air is rushing under the wing, which, as you know, is slightly tipped, and a partial vacuum is formed on top of the wing. Then the reaction between this vacuum and the force of the air rushing underneath the wings tends to support the wing. This wing, or panel, is made large enough to support the whole body of the airplane. All this ratio between the power, the slant, or angle of incidence, of the wings, the wind resistance, the weight of the machinery, etc., must be carefully calculated by highly trained mathematicians, who make this their business.

''The propeller is to the airplane what it is to the boat, and it acts on the same principle, namely, that of pushing in the case of a pusher, or pulling in the case of a tractor, its way through the air. It is this power which pulls the airplane along fast enough to keep it in the air.

''Underneath the airplane, you see two small wheels, and near the tail a small peg.'' He is pointing to a training machine which is circling above our heads. ''This is the landing gear. The wheels are rubber tired and are mounted on shock absorbers, which, as you see, are part of the construction which is fastened to the body, or fuselage, directly under the lower wing. These are to take up the shock of landing. The peg at the rear of the machine serves as a brake and as a support to keep the tail off the ground.''

We are now entering a building in which the manufacture of propellors is progressing.

We are surprised to see so many men in the building, since we imagined that everything would be done by machinery. Our guide looks at us and smiles.

''Yes, they are all made by hand,'' he says.

''Here is where the propellor is shaped,'' he continues, pausing by a buzzing band saw. ''Each layer of wood is sawed into shape right here. Then the pieces are taken into a glue room, heated and glued together. They dry slowly, and then they are smoothed into shape by drawing knives, or in some cases by a routing machine. After they have been smoothed sufficiently they are tested for pitch. Pitch is the distance a propellor would screw through the air were the air solid and were

there no slip. Then the 'slip' of the propellor must be reckoned with. That is, if the propellor had a pitch of ten feet it might advance the machine only seven feet. This would mean a slip of three feet."

Our guide tells us about the difference in the shapes of different propellors which are being, and have been, used.

Soon, we come to a room full of queer looking apparatus. There are odd derricks, scales, levels and all manner of apparatus. Our guide informs us that this is the testing room. Here is where propellors are accepted or discarded.

Then we pass on to another building where the construction of the wings is progressing.

"The wings," our guide informs us, "are the main parts of an airplane. They are the supporting surfaces. Great care must be taken to get them smooth and entirely free from bumps or blemishes in construction. Then, to insure smoothness, they are coated with 'dope.'

"The fuselage, or body, is made of a canvas covered skeleton of black walnut and spruce woods. It is so built that it has a stream line effect. This means that it is shaped like a fish."

Then we see a part of the building where a completed fuselage is sitting, and on it mechanics are working to determine the "angle of incidence" and the "stagger."

Our friend, the guide, points this out as we stand there watching. He probably notices our perplexed look, and explains his terms.

"Stagger," he says, "is the horizontal distance from the front tip of one wing to the corresponding tip of the other. You see," he said, pointing to a finished machine which could be seen through the open door, "one plane is set back from the other. Well, this distance which it is set back is the stagger. This stagger can be computed by the weight of the machine, for if the stagger is too great the machine will be nose heavy, and if too little, tail heavy.

"Now for the angle of incidence. See that plane out there? You notice that each wing is tipped somewhat. This is the angle of incidence. Obviously, it is for the purpose of lifting the machine off the ground. Also, you can see that the greater the angle, the less speed. That plane which you see out there

has two degrees, a hydro-airplane four, and so on according to the size and power of the machine.

"It is getting late," he remarks, pulling out his watch, "but we can see some more buildings and what they contain."

We pass hurriedly through a few more buildings, and in every case we see many people hard at work, but there is one thing which we notice especially. That is the number of mathematicians. In every building is a force of well trained mathematicians. Many branches of mathematics are used. Here we see a man calculating the distance a certain machine can travel on so much gasoline. He is using arithmetic and algebra. Over there is a young man drawing plans for airplanes. Everything must be carefully calculated so as to get the proper ratio between lift, drift and power. Our guide tells us that these men—most of them young men—are drawing excellent salaries.

We think that since we are there we might as well take a look at the hangars, or airplane garages, on the way out, so we walk over that way.

We walk around the field, gazing at the planes and hangars. While we are so engaged, our guide tells us of some of the problems which an aviator runs up against. The talk drifts to cross country flying. I ask our friend how an aviator can tell whether he can go so far and return, or whether his gasoline would give out.

"Well, here is a little illustration," he starts out. "I shall show you this problem in a way which will be easy to understand. There is a shorter way, but it seems rather complicated, unless it can be seen down on paper. I shall show you in a way which is a little longer. When I was in training camp, it was the custom, and is still, for a student to take a solo cross country flight. I had to take it, and so did the rest.

"When my turn came, there was quite a wind blowing. I had to calculate how far I could go and return on three and one-half hours' gas. This is how I did it. First, by means of an instrument which I shall not try to describe I found the wind to be blowing at the rate of forty miles an hour. One must always allow a half hour of gasoline for climbing and for margin. This leaves three hours, which at seventy-five miles an hour is two hundred twenty-five miles, or one hundred twelve

miles out and one hundred twelve miles back. As I was to go directly against the wind, the radius of my flight was altered as follows: My speed outward was seventy-five minus forty miles an hour, or thirty-five miles per hour, and the speed on the return trip, seventy-five plus forty miles an hour, or one hundred and fifteen miles an hour, or three and twenty-nine hundredths times as fast and occupying a time which I shall call X. The time on the outward trip would then be three and twenty-nine hundredths X, a total time of three and twenty-nine hundredths X plus X, or one hundred eighty minutes. By algebra, we find that X is equal to forty-two minutes for the return trip and one hundred thirty-eight minutes as the outward. The distance covered on the outward trip is then one hundred thirty-eight sixtieths of thirty-five, or eighty and five-tenths miles. This is the radius of flight.

"Oh, yes," he remarks, noting the dazed expression on our faces, "you'll need mathematics if you expect to be aviators. In fact," he says, "if some boys hadn't studied mathematics when they were in school we would not have the airplane today."

We have now reached the place where we entered. Our friend shakes our hands warmly as we leave, and, after we have thanked him, he offers to help us in any way possible if we should decide to become aviators.